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TRANSFORMER

The present invention relates to a power transformer comprising at least one high voltage winding and one low 5 voltage winding.

The term "power transformer" as used herein means a transformer having a rated output from a few hundred kVA to more than 1000 MVA and a rated voltage from 3-4 kV to very 10 high transmission voltages, e.g. from 400-800 kV or higher.

Conventional power transformers are described in e.g. A.C.Franklin and D.P.Franklin, "The J & P Transformer Book, A Practical Technology of the Power Transformer", published 15 by Butterworths, 11th edition, 1990. Problems related to internal electric insulation and related topics are discussed in e.g. H.P.Moser, "Transformerboard, Die Verwendung von Transformerboard in Grossleistungstransformatoren", published by H.Weidman AG, 20 Rapperswil mit Gesamtherstellung: Birkhäuser AG, Basle, Switzerland.

In transmission and distribution of electric energy transformers are exclusively used for enabling exchange of 25 electric energy between two or more electric systems. Transformers are available for powers from the 1 MVA region to the 1000 MVA region and for voltages up to the highest transmission voltages used today.

30 Conventional power transformers comprise a transformer core, often formed of laminated commonly oriented sheet, normally of silicon iron. The core is formed of a number of legs connected by yokes which together form one or more core windows. Transformers having such a core are usually called 35 core transformers. A number of windings are provided around the core legs. In power transformers these windings are almost always arranged in a concentric configuration and distributed along the length of the core leg.

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Whilst the casings 6 and 8 are described as "semi-conducting" they are in practice formed from a base polymer mixed with carbon black or metallic particles and have a volume resistivity of between 1 and $10^5 \Omega \cdot \text{cm}$, preferably 5 between 10 and 500 $\Omega \cdot \text{cm}$. Suitable base polymers for the casings 6 and 8 (and for the insulating layer 7) include ethylene vinyl acetate copolymer/nitrile rubber, butyl grafted polythene, ethylene butyl acrylate copolymer, ethylene ethyl acrylate copolymer, ethylene propene rubber, polyethylenes of low density, poly butylene, poly methyl pentene, and ethylene acrylate copolymer.

The inner semiconducting casing 6 is rigidly connected to the insulating layer 7 over the entire interface therebetween. Similarly, the outer semiconducting casing 8 is rigidly connected to the insulating layer 7 over the entire interface therebetween. The casings 6 and 8 and the layer 7 form a solid insulation system and are conveniently extruded together around the wire strands 5.

Whilst the conductivity of the inner semiconducting casing 6 is lower than that of the electrically conductive wire strands 5, it is still sufficient to equalise the potential over its surface. Accordingly, the electric field is distributed uniformly around the circumference of the insulating layer 7 and the risk of localised field enhancement and partial discharge is minimised.

The potential at the outer semiconducting casing 8, which is conveniently at zero or ground or some other controlled potential, is equalised at this value by the conductivity of the casing. At the same time, the semiconducting casing 8 has sufficient resistivity to enclose the electric field. In view of this resistivity, it is desirable to connect the conductive polymeric casing to ground, or some other controlled potential, at intervals therealong.

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According to still another advantageous embodiment, at least two adjacent layers have substantially equal thermal expansion coefficients. In this way thermal damages to the winding is avoided.

- 5 Another aspect of the invention provides a method of winding a transformer as defined in claim 18.

To explain the invention in more detail, embodiments of the transformer according to the invention will now be
10 described by way of example only with reference to the drawings in which:

Figure 1 shows an example of the cable used in the windings of the transformer according to the invention;

Figure 2 shows a conventional three-phase transformer; ✓

- 15 Figures 3 and 4 show in cross-section different examples of the arrangement of the low and high voltage windings of the transformer of the invention; and

Figure 5 shows a method of winding the transformer.

- 20 Figure 3 is a cross-section through the portion of the windings of a power transformer according to the invention within the transformer core 22. A layer of a low voltage winding 26 is located between two layers of a high voltage winding 28. In this embodiment the transformation ratio is
25 1:2.

The direction of the current in the low voltage winding 26 is opposite to the direction of the current in the high voltage winding 28 and the resulting forces from
30 the currents in the low and high voltage winding consequently partially cancel each other. This possibility of reducing the effect of current induced forces is of great importance, especially in case of a short circuit.

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Struts 27 of laminated magnetic material, including spacers 29 providing air gaps, are located between the windings 26, 28 for improving transformer efficiency.

Cancellation of short circuit forces can be improved even further by splitting the turns of the low voltage winding into a number of subturns connected in parallel, preferably such that the total number of low voltage turns becomes equal to the number of high voltage winding turns. Thus, if the transformation ratio amounts to e.g. 1:3 each turn of the low voltage winding is split into three subturns. It is then possible to mix the low and high voltage windings in a more uniform pattern. An optimum arrangement of the windings is shown in Figure 4, where low and high voltage winding turns 30 and 32 respectively are arranged symmetrically in a chessboard pattern. In this embodiment the magnetic fields from each turn of the low and high voltage windings 30, 32 substantially cancel each other and short circuit forces are almost completely cancelled.

When splitting a winding turn into a number of subturns the conducting area of each subturn can be reduced correspondingly since the sum of the current intensities in the subturns remains equal to the current intensity in the original winding turn. Thus no more conducting material, (normally copper), is needed when splitting the winding turns, provided that other conditions are unchanged.

Figure 5 schematically shows how the transformer of the invention can be wound. A first drum 40 carries a high voltage conductor 42 and a second drum 44 carries a low voltage conductor 46. The conductors 42, 46 are unwound from the drums 46, 44 and wound onto a transformer drum 48, all three drums 40, 44, 48 rotating simultaneously. Thus the high and low voltage conductors can easily be intermixed. Joints can be provided between different winding layers.

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